On the General Circulation of the Atmosphere.

SEVERAL years ago, I commenced to gather from old sea journals, such information as they might be found to contain, relating to the winds and currents of the sea, and to embody the information so obtained in a series of charts, in such a manner as to show by pictures, the prevailing direction of the winds and currents for every month, and in every part of the ocean. Indeed, the plan of the undertaking was to collect the experience of every navigator, and to present the combined results of the whole in such a manner, that each one might, with a glance, have the benefit of the experience of all who had preceded him in any of the frequented parts of the ocean.

This enterprize has been seconded by the government and individuals. American ship-masters generally have come into it with great zeal. They make the observations required on every voyage, and send them to me at Washington. There are some thousands or more ships voluntarily co-operating with me in all parts of the ocean, and as it might be supposed, from such a number of active and intelligent observers, we are collecting materials of great value.

During the course of these investigations, many interesting facts are developed, amounting, in some cases, to actual discoveries of great interest—such as a new route, which shortens the sailing distance to the Equator, some fifteen or twenty per cent, and, of course, proportionately to all ports beyond. The existence in the North Atlantic of a regular Monsoon, and in the North Pacific near the West coast, of a perpetual South-West Trade Wind, near the Equator, a unique phenomenon, also, the existence, near the same place, of a system of Monsoons.

My present purpose, however, is not to speak of the discoveries, but rather to treat of the insight which these investigations, undertaken on such a large scale, affords as to the general system of atmospherical circulation over the earth.

They teach us to regard the atmosphere as a vast machine.

It is a sewer into which with every breath we cast vast quantities of dead animal matter. It is a laboratory, into which, when the light and heat enter, they act upon this dead matter, decompose it, and resolve it into gaseous substances, to be by their action again condensed into plants and trees.

If it were not for this condensation, the air would become tainted;

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it would send its impurities back into the lungs; and continually receiving back more in return, it would finally become unfit for the respiration of certain animals, and man would perish from the face of the earth.

We hunger and take food that has been gathered from the vegetable kingdom, into the stomach, there it is elaborated into flesh and blood. After it has coursed through the system, and performed its office, it is again cast forth into the atmosphere, to be reconverted into more vegetables, to serve as food for other animals. Doubtless the animal and vegetable kingdoms are in exact counterpoise: the one destroying, the other re-arranging and rendering fit for use again, this same dead animal matter. In infinite wisdom, the two kingdoms are so balanced that there is not an insect to much on one side, nor a green leaf too little on the other.

These operations are carried on daily and hourly through the atmosphere which we are breathing. How important and profitable therefore, does the study of its laws become!

It is an engine which pumps our rivers up from the sea, and carries them through the clouds to their sources in the mountains. Air and water are the great agents of the sun in distributing his heat over the surface of the globe, cooling this climate and tempering that; and in this light, I propose to consider the winds and the currents.

Though the winds blow here from the four quarters, and sometimes with such violence as to fill the mind with sentiments of awe, and emotions of terror, yet such winds, in comparison with the general system of atmospheric circulation, are but eddies to the main current. They have no more effect in deranging or disturbing that system of circulation, than the shower which they bring with them has upon the Gulf Stream and other great currents of the sea.

From the parallel of about 30° north and south, nearly to the Equator, we have two zones of perpetual winds, viz: the zone of north-east trades on this side, and of south-east on that. They blow perpetually, and without a moment's interruption, the year round. They are as steady and as constant as the current of the Mississippi river—always moving in the same direction.

As these two currents of air are constantly flowing from the Poles towards the Equator, we are safe in assuming that the air which they keep in motion must return by some channel to the place near the Poles, whence it came, in order to supply the trades. If this were not so, these winds would soon exhaust the Polar regions of atmos-

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phere, and pile it up about the Equator, and then cease for the want of air to make more wind of.

This return current, therefore, must be in the upper regions of atmosphere, at least until it passes over those parallels between which the trade winds are always blowing on the surface. The return current must also move in the direction opposite to the direction of that wind which it is intended to supply. The direct and counter currents are also made to move in sort of spiral or loxodromic curves, turning to the west from the Poles to the Equator, and in the opposite direction from the Equator towards the Poles.

This motion is caused by the motion of the earth on its axis.

The earth, we know, moves from west to east. Now, if we imagine a particle of atmosphere at the North Pole, where it is at rest, to be put in motion in a straight line towards the Equator, we can easily see how this particle of air, coming from the Pole, where it did not partake of the diurnal motion of the earth, would, in consequence of *vis inertia*, find, as it travels south, the earth slipping under it, as it were, and thus it would appear to be blowing from the north-east and going towards the south-west.

On the other hand, we can perceive how the particles of atmosphere that start from the Equator to take the place of the other at the Pole, would, as it travels north, and in consequence of its *vis inertia*, be going towards the east faster than the earth. It would, therefore, appear to be blowing from the south-west and going towards the north-east, and exactly in the opposite direction to the other. Writing south for north, the same takes place between the South Pole and the Equator.

Now, this is the process which is actually going on in nature, and if we take the motions of these two particles as the type of the motion of all, we shall have an illustration of the great currents in the air, the Equator being a node, and there being two systems of currents—an upper and an under—between it and each Pole.

Let us return now to our northern particle, and follow it in a round from the Pole to the Equator and back again, supposing it, for at present, merely to turn back after reaching the Equator.

Setting off from the polar regions, this particle of air, from some reason, which does not appear to have been satisfactorily explained by philosophers, travels in the upper regions of the atmosphere, until it gets between the parallels of 30° and 40°. Here it meets, also in the clouds, the particle that is going from the Equator to take its place at the Poles.

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Between these two parallels, then, these two particles meet, press against each other with the whole amount of their motive power, produce a calm and an accumulation of atmosphere sufficient to balance the pressure from the two winds North and South.

From under this bank of calms, two surface winds are ejected, if you please, one towards the Equator, as the north-east trades—the other towards the Poles, as the south-west passage winds, supposing that we are now considering what takes place on this hemisphere only.

These winds come out at the lower surface of the calm region, and consequently the place of the air borne away in this manner is supplied by downward currents from the super-incumbent air of the calm region.

Like the case of a vessel of water which has two streams running in at the top, and two of equal capacity discharging in opposite directions at the bottom. The motion of the water in the vessel is downward.

The barometer, in this calm region, stands higher than it does either to the north or to the south of it; and this is another proof as to the banking up here of the atmosphere.

Following our imaginary particle of air from the north across this calm belt, we now feel it moving on the surface of the earth as the north-east trade wind, and as such it continues on till near the Equator, where it meets a like particle, which has blown as the south-east trades.

Here there is another meeting of winds, and another calm region, for a north-east and south-east wind cannot blow at the same time in the same place. The two particles have been put in motion by the same power; they meet with equal force, and, therefore, at their place of meeting, are stopped in their course. Here there is also a calm belt.

Warmed by the heat of the sun, and pressed on each side by the whole force of the north-east and south-east trades, they ascend—the reverse of the operation which took place at the other meeting near the parallel of 30°.

This imaginary particle now returns to the upper regions of the atmosphere again, and travels there until it meets its fellow particle from the north, where it descends as before, and continues on towards the Pole as a surface wind from south-west.

Entering the Polar regions obliquely, it is pressed upon by similar currents coming from every meridian, and approaching the higher parallels more and more obliquely, until our imaginary particle, with

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all the rest, is whirled about the Pole in a continued circular gale, until, reaching the vortex, it is carried upwards to the regions of atmosphere above, in which it commences again its circuit to the south.

If we imagine this sheet to be a perpendicular section through the atmosphere, from the Polar to the Equatorial regions, and on it trace the track of our imaginary atom of air, it will describe a sort of true-lover's knot or figure of 8.

Thus: commencing at the north, it goes in the upper regions as an atmospherical current, until it arrives between the parallels of 30° and 40°.

Here, in the calm region, it descends and becomes a surface current in the shape of the north-east trades; arrived near the Equator, it is becalmed, ascends, and commences its return to the north as an upper current, till it reaches the calm regions of the "Horse Latitudes," where it is again becalmed. Here, though, instead of ascending, as at the Equator, it descends, and is felt as the south-west passage wind, and thus the circuit is complete.

The Bible frequently makes allusions to the laws of nature, their operation and effects. But such allusions are often so wrapped in the folds of the peculiar and graceful drapery with which its language is occasionally clothed, that the meaning, though peeping out from its thin covering all the while, yet it lies, in some sense, concealed, until the lights and revelations of science are thrown upon it—then it bursts out and strikes us with more force and beauty.

As our knowledge of nature and her laws has increased, so has our understanding of many passages in the Bible been improved.

The Bible called the Earth a "round world," yet for ages it was a most damnable heresy for Christian men to say, the world is round; and, finally, sailors circumnavigated the globe, proved the Bible to be right, and saved Christian men of science from the stake.

"Canst thou tell the sweet influences of the Pleiades?"

Astronomers of the present day, if they have not answered the question, have thrown so much light upon it as to show that, if ever it be answered by man, he must consult the science of Astronomy.

It has recently been all but proved, that the Earth and Sun, with their splendid retinue of comet, satellite and planet, are all in motion around some point or centre of attraction inconceivably remote, and that that point is in the direction of the star Alcyon, one of the Pleiades!

And as for the general system of atmospherical circulation, which

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I have been so long endeavoring to describe, the Bible tells it all in a single sentence: "The wind goeth towards the south and turneth about unto the north; it whirleth about continually, and the wind returneth again according to his circuits." Ecc. i, 6.

A like operation takes place in the southern hemisphere. We now see the general course of the "wind in his circuits," as we see the general course of the water in a river. There be many abrading surfaces, irregularities, etc., which produce a thousand eddies to the main stream, yet, nevertheless, the general direction of the whole is not disturbed nor affected by those counter currents; so with the atmosphere and the variable winds which we find here. But, to return: In the lower half of the loop the wind is permanently from the north-east; in the upper half it prevails from the southward and westward. Hence, the passage of sailing vessels is so much shorter from New-York to England than from England back this way—the difference is as 2 to 3.

We see, also, that there must be about the earth three zones, in which calms are the prevalent condition of the air. One of these zones is near the Equator, where the north-east and south-east trade winds meet and form what is called the Equatorial calms.

The other zones lie between those parallels where the "wind that goeth towards the south" meets that which "turneth about unto the north."

These zones are several degrees of latitude in breadth, and that in the North Atlantic is known as the "Horse Latitudes," from the circumstance that vessels bound with loads of horses from New-England to the West Indies were generally unfortunate here. This trade in horses was very great, and, in the time of stage coaches. consisted of old horses, which, having been broken down here, were taken up, fattened and shipped off to the West Indies.

In crossing this zone, it often happened that the calms were so uninterrupted that the vessel would be detained there many days, during which the horses would drink up all the water, become frantic with thirst, and the whole, or a part, would then have to be thrown overboard. Hence, the name of "Horse Latitudes" for this zone. There is a duplicate to this zone in the southern hemisphere. These three zones encircle the Earth.

About each pole we have, or, according to the views I have been endeavoring to make plain, we ought to have, a perpetual whirlwind.

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The wind approaches the North Pole by a series of spirals from the south-west. If we draw a circle about the Pole, we shall see that the wind enters all parts of this circle from the south-west, consequently the whirlwind is created thereby, which revolves from right to left, or against the hands of a watch.

At the South Pole the winds come from the north-west, and consequently here they revolve about it with the hands of a watch.

It is a singular coincidence between these two facts thus established, and other facts which have been observed, and which have been set forth by REDFIELD, REID, PIDDINGTON and others, viz: that all rotary storms in the northern hemisphere revolve as do the whirlwinds about the North Pole, viz: from right to left, and that all circular gales in the southern hemisphere revolve in the opposite direction, as does the whirl about the South Pole.

How can there be any connection between the rotary motion of the wind about the Pole and the rotary motion of it in a gale caused here by local agents?

So far, we see how the atmosphere moves; but the atmosphere, like every other department in the economy of nature, has its offices to perform; and they are many. I have already alluded to some of them. But I only propose in this paper to consider some of the meteorological agencies which, in the grand design of creation, have been assigned to this wonderful machine.

To distribute moisture over the surface of the earth, and to temper the climate of different latitudes, are two of the great offices assigned by their Creator to the ocean and the air.

When the north-east and the south-east trades meet and produce the Equatorial calms of the Atlantic, the air by this time is heavily laden with moisture—for, in each hemisphere it has travelled obliquely over a large space of ocean. The two winds meet here with opposing forces so nicely balanced that they neutralize each other, and a calm is the consequence; and, as one is pressing from the north and the other from the south, upon the atmosphere over this calm region, each with the whole amount of force that sets it in motion, we ought to have in this calm region an accumulation of atmosphere equal to the sum of those forces. Now, if we had barometrical determinations accurately made in the region of these calms, we should probably obtain an expression, in horse power, if you please, of the whole amount of force exerted by the sun in keeping up this system of atmospherical circulation—for it is the heat of the sun which causes

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the winds to blow and the waters to flow; at least, it is the chief source of their motive power.

The air of the Equatorial calms being charged with moisture, is thus compressed, and has no room for escape, but in the upward direction. In this direction it reaches a cooler region; a portion of its vapor is condensed, and comes down in the shape of rain. Therefore it is, that under these calms we have a region of constant precipitation.

Old sailors tell us of such dead calms of long continuance here, of such heavy and constant rains, that they have scooped up fresh water from the surface of the sea.

The conditions to which this air is exposed here under the Equator are probably not such as to cause it to precipitate all the moisture that it has taken up in its long sweep across the waters.

Let us see what becomes of the rest—for nature, in her economy, permits nothing to be taken away from this earth which is not to be restored to it again in some form, and at some time or other.

Consider the great rivers—the Amazon and the Mississippi for example—we see them day after day, and year after year, discharging an immense volume of water into the ocean.

"All the rivers run into the sea, yet the sea is not full." Ecc. i, 7.

Where do the waters so discharged go, and where do they come from?

They come from their sources you will say. But whence are their sources supplied?—for, unless what the fountain sends forth be returned to it again, it will fail and be dry.

We see simply, in the waters that are discharged by these rivers, the amount by which the precipitation exceeds the evaporation throughout the whole extent of valley drained by them—and by precipitation I mean the total amount of water that falls or is deposited, whether as dew, rain, hail or snow.

The springs of these rivers are supplied from the rains of heaven, and these rains are formed of vapours which are taken up from the sea, that "it be not full," and carried up to the mountains through the air.

"Note the place whence the rivers come, hither they return again," is a dictum of the wise man.

Behold now the waters of the Amazon, of the Mississippi, the St. Lawrence, and all the great rivers of America, Europe and Asia, lifted up by the atmosphere, and flowing in invisible streams through

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the air back to their sources, and that through channels so regular, certain, and well defined, that the quantity taken up one year with the other is nearly the same, for that is the quantity which we see running down to the ocean through these rivers, and the quantity discharged annually by each is, as far as we can judge, as constant.

We now begin to see what a powerful machine is the atmosphere, and though it is apparently so capricious and wayward in its movements, here is evidence of order and arrangement which we must admit, and proof which we cannot deny, that it performs this mighty office with regularity and certainty, and is therefore as obedient to law as the steam engine to the will of its builder.

It too is an engine. The South Seas themselves in all their vast extent are the boiler for it, and the northern hemisphere is its condenser.

The proportion between the land and the water in the northern hemisphere is very different from the proportion between them in the southern. In the northern hemisphere, the land and water are nearly equally divided. In the southern, there is about ten times more water than land. All the great rivers of the world are in the northern hemisphere, where there is less ocean to supply them. Whence then are their sources replenished? Those of the Amazon are supplied with rains from the Equatorial calms. That river runs E., its branches come from the north and south; it is always the rainy season on one side or the other of it, consequently it is a river without periodic stages. It is always at high water mark. For one half of the year its northern tributaries are flooded, and its southern for the other half. It discharges under the line, and as its tributaries come from both hemispheres, it cannot be said to belong exclusively to either. It is supplied with water from the Atlantic Ocean.

Taking the Amazon therefore out of the count, the Rio de la Plata is the only great river of the southern hemisphere.

There is no large river in New Holland. The South Sea Islands give rise to none, nor is there one worth naming in South Africa.

The great rivers of North America and North Africa, and all the rivers of Europe and Asia, lie wholly within the northern hemisphere. How is it then, considering that the evaporating surface lies mainly in the southern hemisphere, how is it, I say, that we should have the evaporation to take place in one hemisphere and the condensation in the other? The total amount of rain which falls in the northern hemisphere is much greater than that which falls in the

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southern. The annual amount of rain in the North Temperate Zone is half as much again as that of the South Temperate.

How is it then that this vapour gets from the southern into the northern hemispheres, and comes with such regularity that our rivers never go dry and our springs fail not? It is because of the beautiful operations of this grand machine—the atmosphere. It is exquisitely and wonderfully counterpoised. Late in the fall, throughout the winter, and in early spring, the Sun is pouring his rays with greatest intensity down upon the seas of the southern hemisphere, and this powerful engine which we are contemplating is pumping up the water there for our rivers with the greatest activity. At this time, the mean temperature of the entire southern hemisphere is about 10° higher than the northern.

The heat which this heavy evaporation absorbs becomes latent, and with the moisture is carried through the upper regions of the atmosphere, until it reaches our climates. Here the vapour is formed into clouds, condensed and precipitated. The heat which held this water in the state of vapour is set free, it becomes sensible heat, and it is that which contributes so much to temper our winter climate. It clouds up in winter, turns warm, and we say we are going to have falling weather. That is because the process of condensation has already commenced, though no rain or snow may have fallen, and we feel this southern heat that has been set free in the process.

While evaporation is going on with most activity in the southern hemisphere, precipitation is taking place to the greatest extent here; the fall spell, the winter rains, and the "long season in May," are familiar times of wet weather to us all. These are the seasons at which we look for high water, and expect our "inland seas" to be in good navigable order.

The vapour comes through the upper regions of the atmosphere, and is probably condensed here not many days after it is taken up there. Suppose it to travel with the velocity of the trade winds, at the rate of twenty miles the hour, it will only take it about twenty days to reach us from the middle of the southern hemisphere.

We cannot ascend into the upper regions of the atmosphere to see what is going on there; but we have such a train of well established facts derived from observation here below, that reason mounting on them, boldly soars aloft, and confidently asserts knowledge of what is going on there.

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When we see and feel, as in the trade wind region we do day after day the year round, the wind blowing as steadily from the Poles towards the Equator, as the Mississippi runs down to the Gulf, we are forced to the conclusion that as much air, precisely as much as we see here coming from towards the Poles, and going towards the Equator, has to go from the Equator back towards the Poles. If this were not so, there would be an exhaustion, and this wonderful engine that we are considering would break down, for there would finally be a vacuum about the Poles with a tremendous atmospherical accumulation about the Equator.

Recurring to the figure of 8 illustration, and considering both hemispheres, we shall see that the atmosphere, like the string of a musical instrument, has its nodes or points of rest. These nodes serve as escape valves to the winds. In the Equatorial calms, both the N. E. and S. E. trades have run their course on the surface, they are going up to blow as upper currents, and therefore the motion of the air here in these calms, could it be seen and measured, would be upwards; and for the same reason, when the two upper currents meet in the region of Horse Latitudes, the motion of the air is downward, for after passing this node, each upper current becomes a surface wind, and each is going whence the other came.*

Important operations are carried on, and purposes grand in the system of terrestrial economy are subserved by these atmospheric nodes.

This singular fact has been brought out by the investigations which we are conducting at the Observatory with regard to the winds. Our investigations in the Atlantic, for we have not carried them much further, show us that the S. E. trade wind region is much larger than the N. E.—I speak of its extent over the Atlantic Ocean only.

The S. E. trades often push themselves up to 10° or 15° of north latitude, whereas the N. E. trade winds seldom get south of the Equator.

Seeing that there is so much more room for evaporation in the southern than in the northern hemisphere, and that there is so much more precipitation on this than on the other side of the Equator, we

* If this interchange of atmosphere did not take place between the two hemispheres, how would a proper mixture of the air be preserved. In the North there is much more land, and many more plants and animals to corrupt it than in the South, and unless the interchange did take place, there would be reason to infer a difference as to atmospherical purity in the two hemispheres.

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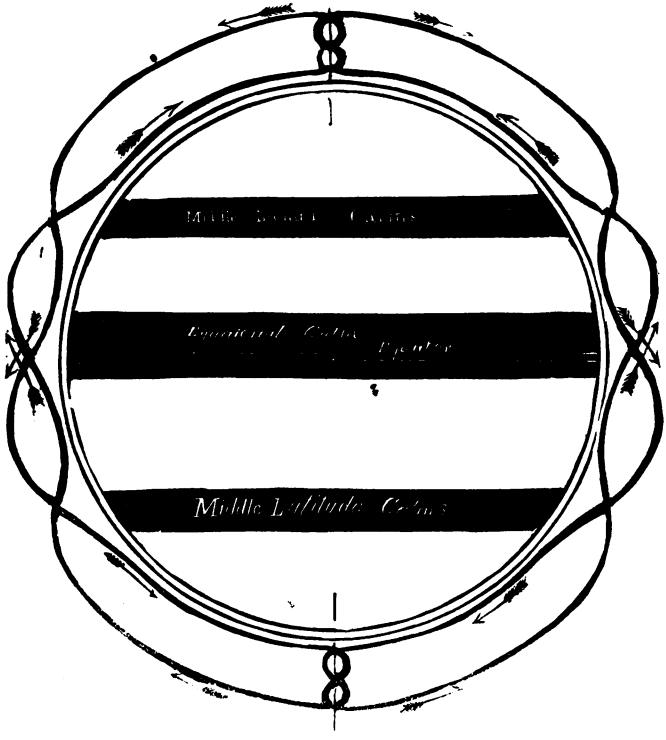
are led to one of two conjectures; first, that aqueous vapour in its invisible state can permeate the atmosphere; in other words, it can flow through the air in separate or independent currents of its own, like some of the gases. In this case, we must further conjecture the seat of some power unknown, which would always drive this vapour from the southern over into the northern hemisphere. We know of no such force in nature, and in this age men would scarcely receive such a conjecture.

Abandoning this therefore, we are next led to the second conjecture, which is, that the motion of the air in the general system of circulation is not such as represented in the figure already described; but that the N. E. trade winds for instance, when they reach the Equatorial calms, instead of turning back towards the north, as is there supposed, keep on towards the south, and the S. E. trade winds make the tour north. In this case, the course of them, as described by SOLOMON, would be thus:



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If this be a true representation of the course of the winds, we shall see that the S. E. trade winds would enter the northern hemisphere, and bear into it all their moisture, except that which is compressed in the region of Equatorial calms.

That the Zone over which the S. E. trade winds blow is of an area greater than that over which the N. E. trade winds blow, does not go to show by any means that the body of air flowing from the South Pole to the Equator, is greater than that which comes from the North Pole to meet it.

All that is necessary to establish a perfect equilibrium between the two winds—and no doubt they are in nature truly counterpoised—is to suppose that they extend to the same height, and blow with equal velocity. In this case, we can readily perceive how the whole amount of air which the N. E. trades daily bear across the parallel of 10° N. for instance, is equal to the whole amount which the South East trades bear across the parallel of 10° S. in the same time.

I have no observations bearing directly upon this point; but we know by whom this mighty atmospherical engine was built, and that his works are never out of order; they are always in the proper proportions and in exact counterpoise.

The South Sea then supplies mainly the water for this engine, while the northern hemisphere condenses it; we should therefore have more rain in the northern hemisphere—the rivers tell us that on our side of the Equator, the great water courses of the globe and half the fresh water in the world, is found in our northern and this alone.

The rain gauge tells us also the same story. The yearly average of rain in the North Temperate Zone is, according to JOHNSON, 37 inches. He gives but 26 in the South Temperate.

Moisture is never extracted from the air by subjecting it from a low to a higher temperature, but the reverse. Thus all that air which comes loaded with moisture from the other hemisphere, and is borne into this by the S. E. trade winds, travels in the upper regions of the atmosphere until it reaches the horse latitudes—here it becomes the surface wind that travels to the northward and eastward. As it goes north it grows cooler, and the process of condensation commences.*

* The peculiar clouds of the trade winds are formed between the two currents of air. They are formed of vapour condensed from the upper current, and evapo-

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We may now liken it to the wet sponge, and the decrease of temperature to the hand that squeezes that sponge. Finally, all the moisture that a dew point of zero, and even far below, can extract, is parted with, and this air then commences "to return according to his circuits" as dry atmosphere; it does not come in contact with the surface of the water, but remains isolated in the upper regions from all sources of vapour, until it crosses the "Horse Latitudes," and commences to blow the trades. Here, it is as the dry sponge, taking up and evaporating fresh water from the sea with great avidity. By the time these winds reach the Equatorial calms, they are saturated with moisture; thus loaded, they return to refresh the earth with rain, to cover the hills with snow, and to supply the fountains of our great rivers with water.

By reasoning in this manner, we are led to the conclusion that our rivers are supplied with their waters principally from the trade wind regions—the northern rivers from the southern trades, and the southern rivers from the northern trade winds.

If this be so, then the saltest portion of the sea should be in the trade wind regions, where the water for all the rivers is evaporated—and there the saltest portions are found.

Dr. RUSCHENBERGER, of the Navy, on his late voyage to India, was kind enough to conduct a series of observations on the specific gravity of sea water.

In about the parallel of 17° N. and S.—the middle of the trade wind regions—he found the heaviest water. Though so warm, the water here was heavier than the cold water to the south of the Cape of Good Hope.

In summing up the evidence in favor of this view of the general system of atmospherical circulation, it remains to be shown how it is, if the view be correct, there should be smaller rivers, or less rain in the southern hemisphere.

The N. E. trade winds returning from the polar regions where the moisture has been compressed out of them, remain, as we have seen, dry winds until they cross the Zone of "Horse Latitudes," and are felt on the surface as the N. E. trades. About two-thirds of them only can there blow over the ocean, the rest blow over the land,

rated as it descends, by the lower and dry current forms from the Poles. It is the same phenomenon up there which is so often observed here below; when a cool and dry current of air, meets a warm and wet one, an evolution of vapour or fog ensues.

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over Asia, Africa and North America, where there is but comparatively a small portion of evaporating surface exposed to them.

The Zone of these trades extends from about 25° North to the Equator. Now if we examine the globe to see how much of this Zone is land and how much water, we shall find, commencing with China and coming over Asia, the broad part of Africa, and so on across this Continent to the Pacific, land enough to fill up as nearly, or it may be, just one-third of it, equal to 120° of longitude.

Two-thirds then only of the N. E. trade winds are fully charged with moisture, and only two-thirds of the rain of the northern hemisphere falls in the southern.

This point of view is one which is not capable of any more than the rudest approximations, for the greater extent of S. E. trades on one side, and of high mountains on the other, must each of necessity have its effect.

These calm and trade wind regions or belts, move up and down the earth in latitude nearly a thousand miles. In July and August, the Zone of Equatorial calms is found between 7° N. and 12° N., in March and April, between lats. 5° S. and 2° N.

With this fact and the chart of the N. E. trades before us, it is easy to perceive why it is that we have a rainy season in Oregon, a rainy and a dry season in California, another at Panama, two at Bogota, none in Peru, and one in Chili.

In Oregon, it rains every month, but more in the winter months. The winter there is the summer of the southern hemisphere, when this steam engine is working with the greatest pressure. The vapour that is taken up by the S. E. trades, is borne along over the region of N. E. trades to lat. 35° or 40°, where it descends and appears on the surface with the S. W. winds of those latitudes. Driving upon the highlands of the Continent, this vapour is condensed and precipitated during this part of the year almost in constant showers.

In the winter, the belt of the "Horse Latitudes" in this hemisphere approaches the Equator. This whole system of Zones, viz.: trades, calms and westerly winds, follows the Sun.

The S. W. winds crowding down at this season to the south, reach as far down as the lower part of California; and the same cause which made it rain in Oregon, now makes it rain in California. As the Sun returns to the North, he brings the belt of "Horse Latitudes" and N. E. trades along with him; and now at places where six months before, the S. W. winds were the prevailing winds, the

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N. E. trades are now found to blow. This is the case in the latitude of California. These N. E. trades then come across the Mountains, the Sierra Nevada and others, and leave all their moisture, if they have any, there. Consequently, when they descend into the valleys beyond, they are cooled down. They have not vapour enough left in them to make rain of, and we have there a cool and rainless season, until the Sun returns to the South, and drags back after him his train of trade wind zones and belts of calms.

Panama is in the region of Equatorial calms. This belt of calms, as may be seen by the charts, travels during the year back and forth over about 17° of latitude, coming furthest North in summer, where it tarries for several months, and then returns so as to reach its extreme Southern latitude sometime in March or April. Where these calms are, it is always raining, and the chart shows that they hang over the latitude of Panama from June to November; consequently, from June to November is the rainy season. The rest of the year Panama is in the region of the N. E. trades, which, before they arrive there, have to cross the Mountains of the Isthmus, on the cool tops of which they deposite their moisture, and leave Panama rainless and pleasant, until the Sun returns North with the belt of Equatorial calms after him. They push the belt of N. E. trades farther to the North, occupy a part of the winter zone and refresh it with summer rains.

This belt of calms moves over more than double of its breadth, and the entire motion from South to North is accomplished generally in two months, May and June.

Take the parallel of 4° N. for instance: during these two months, the entire belt of calms crosses this parallel and then leaves it in the region of the S. E. trades. During these two months, it was pouring down rain on that parallel. After the calm belt passed it, the rains held up, and the people in that latitude have no more of it till the fall, when the belt of calms recrosses the parallel on its way to the South. By examining the "Trade Wind Chart," it may be seen what the latitudes are that have two rainy seasons, and that Bogota is within the bi-rainy latitudes.

The Coast of Peru is within the region of perpetual S. E. trade winds on the verge of this great boiler, and yet it never rains there. The reason is plain and the charts make it obvious.

The S. E. trade winds, which in fact come from about E. S. E., strike the water on the Coast of Africa. They blow obliquely across

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the Atlantic until they reach the Coast of Brazil. By this time they are heavily laden with vapour, which they continue to bear along across the Continent, depositing it as they go, and supplying the sources of the Rio de la Plata and Southern tributaries of the Amazon.

Finally, they reach the snow-capped Andes, and here is wrung out of them the last particle of moisture that that very low temperature can extract.

Reaching the summit, they now tumble down as cool and dry winds in the slopes beyond. Meeting with no evaporating surface, and with no temperature *colder* than that to which they were subjected on the mountain top, they reach the ocean before they become charged with fresh vapor, and before, therefore, they have any which the Peruvian climate can extract. Thus we see how the top of the Andes becomes the reservoir from which are supplied all the rivers of Chili and Peru.

We see, moreover, that the Andes and all other mountains which lie North and South have a dry and a rainy side, and that the prevailing winds of the latitude determine which is the rainy and which the dry side.

Thus the southern coast of Chili: In our summer time, when the Sun comes North, and drags after him his belts of perpetual winds and calms, that part of the coast is left within the regions of the N. W. winds—the winds that are counter to the S. E. trades—which, cooled by the winter temperature of the highlands of Chili, deposite their moisture copiously. During the rest of the year the most of Chili is in the region of the S. E. trades, and the same causes which operate in California to prevent rain there, operate in Chili: only the dry season in one place is the rainy season of the other.

Hence we see that the weather side of all such mountains as the Andes is the wet side, and the lee side the dry.

We shall now be enabled to determine, if the views which I have been endeavoring to present be correct, what parts of the earth are subject to the greatest fall of rain. They should be on the slopes of those mountains which the trade winds first strike after having blown across the greatest tract of ocean.

If, therefore, we commence at the parallel of about 30° N. in the Pacific, where the N. E. winds first strike that ocean, and trace them through their circuits till they first strike high mountains, we ought to find such a place of heavy rains.

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Commencing at this parallel in the North Pacific, the N. E. trades blow thence and reach the region of Equatorial calms, near the Caroline Islands. Here they rise up; but, instead of pursuing the same course in the upper stratum of winds, they, in consequence of the rotation of the earth, are made to take a S. E. course. They keep in this upper stratum until they reach the "Horse Latitudes" of the South, between the parallels of 30° and 40°; after which, they become the N. W. winds of the southern hemisphere, which correspond to the S. W. of the northern. Continuing on to the S. E., they now are the surface winds, and after blowing as such over a considerable tract of ocean, they become as the wet sponge, and are abruptly intercepted by the Andes of Patagonia, whose cold summit compresses them, and with its low dew-point squeezes the water out of them. Capt. KING found the astonishing fall of water here of nearly 13 feet (151 inches) in 41 days.

We ought to expect a corresponding rainy region to be found to the north of Oregon; but there the mountains are not so high, the obstruction to the S. W. winds is not so abrupt, the highlands are farther from the coast, and the air which these winds carry in their circulation to that part of the coast, though it be as heavily charged with moisture as at Patagonia, has a greater extent of country over which to deposite its rain, and consequently the fall to the square inch will not be as great.

In like manner we should be enabled to say in what part of the world the most equable climates are to be found. They are to be found near the Equatorial calms, where the N. E. and S. E. trades meet fresh from the ocean.

Such a place cannot be found in the Equatorial regions of Eastern Africa, because there is but a small evaporating surface for the N. E. trades in the Indian Ocean. Moreover, the course of these winds is interrupted there by other and local causes, which convert them into monsoons.

It cannot be found in Western Africa, because the trade winds approach that part of the continent from the land, and not from the water, and in unequally heated currents, But it is to be found in the valley of the Amazon, where those winds meet after having traversed the Tropics all the way across the Atlantic. By such long contact with an equally heated ocean, the air becomes of a uniform temperature.

The temperature here is so equal that it is considered to be an

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extraordinary and remarkable change in the weather when the mean temperature of any day varies as much as 3° from the mean of the whole year.

Here, too, is where takes place the great condensation of the water which has been taken up from the Atlantic by the two systems of trade winds.

I have never seen the records of a rain gauge kept in the valley of the Amazon; but this river itself is gauge enough to show that the fall of rain there is immense. A rain gauge kept on the verge of it gives the annual fall at 23 feet. In Washington it is about 3—in Charleston 4.

The mean annual fall of rain on the entire surface of the earth is estimated at about 5 feet.

To evaporate water enough from the ocean to cover the earth 5 feet deep with rain; to transport it from one zone to another; and to precipitate it in the right places, at suitable times, and in the proportions due, is the office of the grand atmospherical machine. This water is evaporated principally from the Torrid Zone. Supposing it all to come thence, we shall have, encircling the earth, a belt of ocean 3000 miles in breadth, from which this atmosphere evaporates a layer of water annually 16 feet in depth. And to hoist up as high as the clouds, and lower down again, all the water in a lake 16 feet deep, and 3000 miles broad and 24,000 long, is the yearly business of this invisible machinery. What a powerful engine is the atmosphere!

We see that light is beginning to break upon us—for we now begin to perceive why it is that the proportions between the land and water were made as we find them in nature. If there had been more water and less land, we should have had more rain, and *vice versa*, and then climates would have been different from what they now are, and the inhabitants, neither animal nor vegetable, would have been as they are. And as they are, that wise Being, who, in his kind Providence, so watches over and regards the things of this world that he takes knowledge of the sparrow's fall, and numbers the very hairs of our head, doubtless designed them to be.

In some parts of the Earth the precipitation is greater than the evaporation; thus, the amount of water borne down by every river that runs into the sea may be considered as the excess of the precipitation over the evaporation that takes place in the valley drained by that river.

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In other parts of the Earth the evaporation and precipitation are exactly equal, as in those inland basins such as that in which the city of Mexico, the Caspian Sea, etc. etc., are situated; which basins have no ocean drainage.

If more rain fell in the valley of the Caspian than is evaporated from it, that sea would finally get full and overflow the whole of that great basin. If less fell than is evaporated, then that sea would dry up, and plants and animals would all perish there for the want of water.

In the sheets of water which we find distributed over that and every other inhabitable inland basin, we see reservoirs or evaporating surfaces just sufficient for the supply of that degree of moisture which is best adapted to the well-being of the plants and animals that people such basins.

In other parts of the earth still we find places, as the Desert of Sahara, in which neither evaporation nor precipitation takes place, and in which we find neither plant nor animal.

In contemplating the system of terrestrial adaptations, I have come to regard the great deserts of the earth, as the Astronomer does the counterpoises to his instrument—though they be mere dead weights, they are, nevertheless, necessary to make the balance complete, the adjustments perfect. They give ease to the motions, stability to the performance, and accuracy to the work of his telescope.

Wherever I turn to contemplate the works of nature, I am struck with the admirable system of counterpoises, with the beauty and nicety with which every department is poised by the others; things and principles are meted out in directions the most opposite, but in proportions so exactly balanced and nicely adjusted, that results the most harmonious are produced.

It is by the action of opposite and compensating forces that the earth is kept in its orbit, and the stars are held suspended in the azure vault of heaven, and these forces are so exquisitely adjusted, that at the end of a thousand years, the earth, the sun and moon, and every star is found to return to its proper place at the proper moment.

Nay, Philosophers tell us, when the little snow drop, which in our garden walks we may now see, raising its beautiful head to remind us that spring is at hand, was created, that the whole mass of the earth from pole to pole, and from circumference to centre, was taken into account and weighed, that the proper degree of strength might be given even to this little plant.

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Botanists tell us that the constitution of this plant is such as to require that at a certain stage of its growth, the stalk should bend and the flower should bow its head, that an operation should take place, which is necessary, in order that the herb should produce seed after its kind, and that after this its vegetable health requires that it should lift its head again and stand erect. Now if the mass of the earth had been greater or less, the force of gravity would have been different; the strength of fibre in the snow drop would have been too much or too little; the plant could not bow or raise its head at the right time; fecundation could not take place, and its family would have become extinct with the first individual, because it could not have reproduced itself.

Now if we see such perfect adaptation in the case of one of the smallest flowers of the field, how much more may we not expect it in the atmosphere, upon the right adjustment of which depends not only the life of that plant, but the well being of every individual that is found in the entire vegetable and animal kingdoms of the world.

When the East blinds blow for a little while, they bring us air saturated with moisture from the Gulf Stream, and we complain of the sultry, oppressive, heavy atmosphere, the invalid grows worse, and the well man feels ill, because when he takes this atmosphere into his lungs, it is already so charged with moisture, that it cannot take up and carry off that which encumbers his lungs, and which nature has caused to be deposited there, that this atmosphere may take up and carry off. At other times the air is dry, he feels that it is conveying off matter from the lungs too fast, he realizes the idea that it is consuming him, and he calls it parching.

Therefore, in considering the general laws of atmospherical circulation, in order to get at the clue to them, I have felt myself constrained to set out with the belief, that if the atmosphere had had a greater or less capacity for moisture, or if the proportion of land and water had been different—if the earth, air and water, had not been in exact counterpoise—the whole arrangement of the Animal and Vegetable Kingdoms would have varied from its present state. But God chose to make them what they are; for this purpose it was necessary to establish the proportions between the land and water and the desert just as they are, and to make the capacity of the air to circulate heat and moisture just what it is, and to have it to do all its work in obedience to law, and in subservience to order.

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Else why are we told that "He measured the waters in the hollow of his hand, and comprehended the dust in a measure, and weighed the mountains in scales and the hills in the balance?" Why but that, when he spanned the heavens, he might mete out the atmosphere in exact proportions to all the rest, and impart to it those properties and powers which it was necessary for it to have, in order that it might properly perform all those offices and duties for which he designed it? I have not the time, and if I had the time, I have not the heart so to abuse the patience of those around me, as I should do, by attemtping to take up the currents of the ocean, and to tell of the discoveries to which our system of investigation has led us with regard to those great agents in the terrestrial economy.

Harmonious in their action, they are obedient to law, and subject to order in all their movements; when we consult them in their courses, they teach us lessons—the investigations into that broad spreading circle of phenomena connected with the winds and the waves of the sea, are second to none for the good which they do and the profit which they give.

The Astronomer sees the hand of God in the sky, but the right minded Mariner who looks aloft as he ponders these things, hears His voice in every wave of the sea, and feels His presence in every breeze that blows.

Prof. A. D. Bache, Superintendent of the Coast Survey, then gave a popular account of the Measurement of the Base Line on Edisto Island, of the apparatus used, of the difficulties attending such operations, and the means employed in overcoming the difficulties experienced.

[The article of Prof. C. U. Shepard is inserted here, as the proof was not received in time to insert the article in its proper place.]

Account of three new American Meteorites, with observations upon the geographical distribution of such bodies generally; by Charles Upham Shepard.

1. *Meteoric Stone of Richland, South-Carolina.*

This stone was put into my hands a year ago, by Dr. Robert W. Gibbes, of Columbia, to whom it had been presented by Mrs. English,

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